PMU data analysis and applications

Gert Rietveld
grietveld@vsl.nl
PMUs & Big Data

⇒ What data is relevant?
⇒ What information can we get from it?
Heart beat

We need actionable information!

\[ f = 65 \text{ beats/s} \]

\[ f = 0 \text{ beats/s} \]

patient died

KEEP CALM and...

...ok, not THAT calm!
Data ⇒ actionable information

What presently is weakest link?
Applications in 50 kV distribution ring:

- Power flow
- Voltage variations, voltage stability
- Power swings, oscillations
- Dynamic Line Rating
- State estimation
- Power Quality / PQ propagation

Details: Arjen Jongepier, “PMUs Pilot Project on 50kV Cable Ring”
DLR using PMUs
Line impedance - installation

Double check connections 
(Live connection!)
Accurate knowledge of transmission line parameters helps to improve accuracy in relay settings, post event fault location, transmission power flow modeling, PQ source location, and Dynamic Line Rating (DLR).
Impedance results - DLR

R and L are not constant, depend on current
⇒ What’s wrong?!
Effect PT/CT errors on \( R \)

### Impact of VT amplitude error on resistance in phase L1-Tenhult

- \( R1 = 6.551x + 2.326 \)
- \( R1v = 7.013x + 0.690 \)

### Impact of VT phase error on resistance \( R \) in phase L1-Tenhult

- \( R1 = 0.0516x + 0.8364 \)
- \( R1v = -0.03x + 2.326 \)

<table>
<thead>
<tr>
<th>Resistance ( R )</th>
<th>Sensitivity coefficients</th>
<th>Influence</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Voltage amplitude errors</td>
<td>( \pm 7 \text{ ( \Omega )/%} )</td>
<td>Very high</td>
</tr>
<tr>
<td>2. Voltage phase errors</td>
<td>( \pm 0.04 \text{ ( \Omega )/min} )</td>
<td>High</td>
</tr>
<tr>
<td>3. Current amplitude errors</td>
<td>( \pm 0.02 \text{ ( \Omega )/%} )</td>
<td>Very low</td>
</tr>
<tr>
<td>4. Current phase errors</td>
<td>( -0.004 \text{ ( \Omega )/min} )</td>
<td>Low</td>
</tr>
</tbody>
</table>
Final results - DLR

VT error adjustment -0.11 %, 0.9 min

Applications:

- remote calibration of VTs
- dynamic line rating

Present work: further sensitivity analysis, DLR lab tests
# Fault location

Synchronised measurements for determining fault location

## Results of lab data vs model:

<table>
<thead>
<tr>
<th>Fault location</th>
<th>Actual Fault location (km)</th>
<th>Algorithm (km)</th>
<th>Error 2 (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>4</td>
<td>4.003</td>
<td>0.08</td>
</tr>
<tr>
<td>B</td>
<td>8</td>
<td>8.008</td>
<td>0.10</td>
</tr>
<tr>
<td>C</td>
<td>12</td>
<td>12.02</td>
<td>0.13</td>
</tr>
<tr>
<td>D</td>
<td>16</td>
<td>16.03</td>
<td>0.17</td>
</tr>
<tr>
<td>E</td>
<td>20</td>
<td>20.04</td>
<td>0.20</td>
</tr>
</tbody>
</table>

Present work: real time analysis, purely PMU-based; error sensitivity analysis
Summary

sensors

data flow

applications

action

visualization
VSL – nat.¹ metrology institute

- National Meas. Standards
- Company with public task
  (100 fte, 50 % MSc-PhD)
- Calibrations, ref.materials,
  R&D, consultancy, training
- Independent, reliable, top in
  measurement, international
- Focus: energy, industry

Beyond all doubt

Mass, pressure, viscosity
Thermometry, humidity
Gas analysis
Gas & Liquid flow
Optics, Radiometry
Geometry, Nanometrology
Electricity: DC/LF & HF
Time & Frequency
Ionising Radiation